14066

Paper Number XXXX-2004-XXX-XX

Autonomous Command and Control for Manned Ground Vehicle Crew Aiding Behaviors

Sanjiv Dungrani
U.S. Army RDECOM

Dan Rodgers
Lyle Sutton
General Dynamics Robotic Systems

ABSTRACT

The U.S. Army's Research, Development, and Engineering Command (RDECOM) Tank-Automotive and Armaments Research, Development and Engineering Center (TARDEC) Vetronics Technology Area is responsible for technology applications that support reduced crew operations in ground combat vehicles. The current program meeting this challenge is the manned Crew integration and Automation Test bed (CAT) Advanced technology demonstration (ATD). The CAT is the culmination of past technology efforts that include the Vetronics Technology Test bed (i.e., the intra vehicle electronics suite science and technology objective (STO)), future scout virtual prototype ACT II effort, and Crewmen's Associate ATD.

This is the first of a series of information papers to follow on crew decision aiding. This paper will focus on providing a high level overview of the decision aiding capabilities being implemented for the June 2006 CAT ATD field experiment.

INTRODUCTION

Currently, there are a number of technology areas being explored under the CAT ATD that support a multi-mission capable common crew station and a two-person crew concept. These technology areas include decision aids, an improved Warfighter Machine Interface (WMI) including an indirect vision driving system and driving aids, an advanced electronic architecture design and network topology, and an embedded simulation. [1]

The Command and Control / Intelligent Aiding (C2/IA) Integrated Process Team (IPT) is charted by the CAT ATD Program Manager to develop a crewman's battle command decision support system for a manned ground vehicle. The IPT's objective is to define, design and implement such a real-time system to support the fight (19K), scout (19D), and carrier (11M) Military Occupational Specialties (MOS). The crew aiding component of the CAT ATD is a joint effort between TARDEC, its lead system integrator - General Dynamics Land/Robotic Systems, and Viecore FSD.

The CAT ATD testbed (figure 1) will demonstrate the readiness of decision support technology leading to possible design transition and the integration into the Army's Future Force manned ground vehicles.

TECHNICAL APPROACH

The same DSS will reside on each of the platforms allowing equivalent capabilities and responsibilities. Therefore, all platforms essentially have the same software allowing role-specific (e.g. Vehicle Commander, Gunner, Driver, or Scout) assistance to enable two-man crew operations. The DSS design addresses interfaces to other platforms across an echelon as well as up and down the echelons.

The C2/IA IPT's approach for synthesizing the decision support system include 1) operational concepts and scenarios analysis to derive specific tasks the crew must perform during the course of a mission, 2) Use Cases definition to derive specific crew aiding behaviors (CABs), 3) Use Cases detailing to establish the functional software requirements for our decision support system (DSS), and 4) a software architecture based on the 4D/RCS reference architecture [2].

WARFIGHTER NEEDS DERIVED FROM OPERATIONAL CONCEPT

Many information, automation and communication lessons were learned from a number of wars in the 1990's. Operational concepts have changed significantly along the way and war fighter expectations and needs for a real-time DSS have grown substantially [4]. The changing nature of the war makes it critical to understand the Mounted Warrior's needs as they relate to future systems and operational concepts, specifically the Army's FCS family of manned ground systems such

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
21 JUN 2004	**Journal Article**	**10-05-2004 to 06-06-2004**

4. TITLE AND SUBTITLE
Autonomous Command and Control for Manned Ground Vehicle Crew Aiding Behaviors

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Sanjiv Dungrani; Dan Rodgers; Lyle Sutton

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
General Dynamics Robotic Systems,1234 Tech Court,Westminster,MD,21157

8. PERFORMING ORGANIZATION REPORT NUMBER
; #14066

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army TARDEC, 6501 East Eleven Mile Rd, Warren, Mi, 48397-5000

10. SPONSOR/MONITOR'S ACRONYM(S)
TARDEC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
#14066

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The U.S. Army's Research, Development, and Engineering Command (RDECOM) Tank-Automotive and Armaments Research, Development and Engineering Center (TARDEC) Vetronics Technology Area is responsible for technology applications that support reduced crew operations in ground combat vehicles. The current program meeting this challenge is the manned Crew integration and Automation Test bed (CAT) Advanced technology demonstration (AID). The CAT is the culmination of past technology efforts that include the Vetronics Technology Test bed (i.e., the intra vehicle electronics suite science and technology objective (STO)), future scout virtual prototype ACT II effort, and Crewmen's Associate ATD. This is the first of a series of information papers to follow on crew decision aiding. This paper wilt focus on providing a high level overview of the decision aiding capabilities being implemented for the June 2006 CAT ATD field experiment.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Public Release**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

as the Mounted Combat System (MCS), Command and Control Vehicle (C2V), Reconnaissance and Surveillance Vehicle (R&SV) and Infantry Carrier Vehicle (ICV).

To accomplish this task, C2/IA IPT membership included representatives from the Unit of Action Maneuver Battle Lab (UAMBL) Experimentation and Analysis Directorate (EAD) at Fort Knox. The role of EAD was to help in the development of a militarily significant mission scenario, and corresponding vignettes, representative of what would be fielded in the Army's Future Force.

The mission scenario is divided into segments, called vignettes, to facilitate evaluation of specific Army tasks such as those found in the Army's Universal Task List (e.g. Road March, Tactical Movement, Attach, Assault, Re-Supply, etc.). Each task is then further elaborated through definition of nominal and alternative operational sequences of activity; this last step is captured in the form of Use Cases.

Each Use Case defines (in a simple textual format) the purpose, actors, preconditions, post conditions and a fairly detailed listing of the individual activities involved for the nominal case and any related alternative sequences of activity triggered by a significant event (e.g. enemy contact). This approach provides an easy-to-understand representation of the functional requirements for the autonomous C2 system from the user's perspective. This is an important point since it provides a common frame of reference between the user community, software developers, and experimentation engineers.

Currently, the C2/IA IPT has defined approximately 66 Use Cases grouped into the following categories:

- Planning
- Preparation
- Execution – Maneuver
- Execution – ISR
- Execution – Cooperative Engagement
- Execution – Monitoring and Alerting
- Execution – Logistics Re-Supply

The Use Cases are specific functional descriptions designed to tease out software requirements by breaking down specific "uses" of the software system. These requirements are further analyzed to identify specific crew aiding behavior patterns. By pattern we mean a functional procedure typically performed by the crew. Those patterns that require considerable cognitive or physical effort, and are suitable for implementation in software, are candidate crew aiding behaviors (i.e. CAB) to be provided by the DSS. Each CAB may support one or more Use Cases, and conversely each Use Case may require more than one CAB.

CREW AIDING BEHAVIORS

The CABs are based on the specific needs of the vehicle crew during each vignette. When combined with other CABs or crew activities, they can facilitate many complicated processes. Crew aiding behaviors can take one of the following four forms (loosely related to the "intelligent" process consisting of the observe, orient, decide, act steps, other wise known as the OODA loop made famous by John Boyd [3]):

1. Automated Situation Assessment – modeling the world state based on observations in order to determine its state when relevant to the current purpose/task.
2. Automated Execution Monitoring and Alerting – understanding the situation in order to determine the need to either repair, adapt and/or replace the current plans, and in some extreme case actually change the intent, based on observed world state and a model of intended activity.
3. Automated Planning – developing feasible plans by deciding which to pursue, where and when to carry them out, and who should perform them; decisions are based on high level tasking criteria usually provided as input from the crew.
4. Automated Plan Execution – scheduling and sequencing the execution of a plan's tasks/subtasks; plans need not be automatically generated to be automatically executed, sometimes referred to as an executor.

CABs, when supporting one of the process steps listed above, off-load either cognitive or physical workload for the crew. The "intelligent" process is applied to many operational facets, and so our CABs can potentially provide one or more of the four types of aiding for each battlefield functional area. Based on our mission scenario, approximately 127 CABs have been defined and are grouped into categories that are roughly aligned with the major Intelligent Ground Vehicle taxonomy areas:

- Battle Command (C2)
- Communicate
- Mobility (Move)
- Lethality (Shoot)
- Sense (Look)
- Sustain
- Survive.

ARCHITECTURE

After defining and analyzing the software functions, an appropriate software functional architecture (Figure 2) and design is developed to: provide the necessary CAB functionality; integrate with the other software components such as the Warfighter Machine Interface (WMI); and, to achieve certain "ilities" objectives (e.g. scalablility, flexibility, extensibility, modularity, testability).

The primary software component to be developed is the Decision Support System (DSS) which provides world modeling, event notification, symbolic reasoning, and geometric reasoning services to the WMI. The DSS must integrate with the existing GDRS implementation of the 4D/RCS reference model architecture. The primary components of the Phase I CAT architecture are the WMI, eXternal Autonomous Control (XAC), and autonomous subsystem nodes (e.g. autonomous mobility, autonomous reconnaissance, surveillance and target acquisition or RSTA).

The XAC and subsystem nodes are considered 4D/RCS nodes and follow the GDRS implementation guidelines. The XAC coordinates the activity of the subsystem nodes and the WMI provides commands to and receives status/reports from, XAC. It is important to keep in mind that many WMIs and XACs exist on the battlefield and any WMI can interact with any other WMI and can take control of any XAC. For example, each MCS has two crew stations (i.e. two WMIs) and one XAC; and, an MCS Platoon would have six WMIs, three XACs, and another XAC for each unmanned ground or aerial vehicle.

Each 4D/RCS node consists of an appropriately formulated world model, planner, executer, and sensory processing capability. For nodes that do not directly "sense" the world, but rather share sensed information, the sensory processing function is replaced by an information management function whose purpose is to ensure the right nodes have the right information at the right time relative to their decision making information requirements. Each node has a shell with a similar set of command, status and report input/output interfaces.

Another important point to understand in this autonomous hierarchical control paradigm is that at the top of any 4D/RCS node hierarchy resides a soldier, i.e. a human. The soldier interfaces with the autonomous systems through the WMI. The DSS provides the information management, world modeling, and "planner" for a WMI. If used as an autonomous command and controller for an autonomous platform, the DSS is referred to as an ACC for autonomous C2.

The War-fighter Machine Interface (WMI) layer provides an interface to a crewman, enabling the crewmember to interact with the DSS and to control a vehicle's systems. The DSS is role specific allowing the each crewman to have role specific span-of-control. For example, a gunner would have a span-of-control including RSTA sensors and Effectors where a Platoon Commander would have control over three MCS and any unmanned vehicles.

Each crew member may also control any of the subsystems in a vehicle (e.g. teleoperation of an autonomous mobility or RSTA subsystem). At the bottom of the hierarchy, the system interfaces to physical hardware to perform atomic commands such as steer, accelerate, point, fire, etc.

DECISION SUPPORT SYSTEM DESIGN

The WMI and the DSS make up a 4D/RCS node. The WMI is the executer and the DSS provides the world model and planner. Figure 3 shows the DSS' major components.

Figure 3 shows systems outside the DSS (C2) are labeled as external systems. Each external system communicates with the DSS through a Device Dependent Interface/Data Translation (DDI/DX) component. Each DDI/DX encapsulates the communications protocol used by the external system and translates the external system's data to/from the DSS' world model. Encapsulating communication with external systems in DDI/DX components allows external systems to change independently of the DSS.

The Device Independent Interface (DII) is the public interface through which the DDI/DX components communicate with the DSS. The Message Processor coordinates world model updates, handles planning requests, sends out the results of planning activities and execution monitoring, and runs the rules as needed. Having the Message Processor control when and for how long the rules can run yields efficient use of the Rules Engine (Planner).

The Rules Data (World Model) contains the current operational picture and plan for the vehicle. The world model is continually updated with vehicle status information and other data received from external systems. In accordance with the 4D/RCS architecture, the world model data is continuously shared with other DSSes.

The Rules Engine (Planner) includes an inference engine and analytical helper functions. The inference engine runs execution monitoring and planning rules. Rules depend upon analytical helper functions to perform computationally intensive tasks such as line of sight calculations. Each CAB will be implemented using one or more rules. Separating the rules from the data they operate on allows each rule to be incrementally refined through experience, without requiring changes to the entire collection of rules each time a single rule is modified. This approach simplifies growing and adapting the rules as experience demands.

CONCLUSION

The current plans and present efforts has resulted in completion of Scenario definition, use cases/CABs definitions, and architecture to capture warfighter needs, software requirements, and a preliminary design for Decision Support System, respectively.

The contractor team has already begun integration of software developed from a number of programs including but not limited to the Future Force Warrior (FFW), Robotic Collaboration Technology Alliance, and others.

We will also continue define additional crew aiding behaviors over the next few years to enhance the capabilities of the soldiers in the field.

CONTACT

Sanjiv Dungrani
Computer Engineer
U.S. Army RDECOM-TARDEC
6501 E. 11 Mile Rd.
AMSRD-TAR-R / MS264
Warren, MI 48397-5000
Phone: (586) 574-5696
Fax: (586) 574-8684
Email: dungrans@tacom.army.mil

Dan Rodgers
Electrical Engineer
General Dynamics Robotic Systems
1234 Tech Court
Westminster, MD 21157
Mobile: 410-596-5966
Voice/Fax: 817-598-9089
Email: drodgers@gdrs.com

Lyle Sutton
Software Engineer
General Dynamics Robotic Systems
1234 Tech Court
Westminster, MD 21157
Phone: (443) 394-8979 x314
Fax: (443) 394-7716
Email: LSutton@gdrs.com

REFERENCES

1. Sanjiv Dungrani, Melissa Cummings, Andrew Orlando, "Crew Integration and Automation", 2003 Vehicle Technologies Symposium--Intelligent Systems for the Objective Force, May 2001.

2. Albus James, Huang, Hui-Min, Messina (August 2002), 4D/RCS: A Reference Model Architecture for Unmanned Vehicle Systems Version 2.0.

3. Coram, Robert (2002). BOYD:The Fighter Pilot Who Changed the Art of War, New York: Little, Brown and Company (ISBN 0316881465 (HC), 440 pp.).

4. Adriane Stebbins, "Intelligent Agents for Command and Control and Information Retrieval", Naval Postgraduate School, September 21, 2001.